



Human Spaceflight Recent Conjunctions of Interest

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Human Spaceflight Screening and Notification

During each nine-hour shift (or upon request), the Orbital Safety Analyst (OSA) at JSpOC updates the entire tracked catalog with the latest tracking data from the SSN and screens this catalog against NASA's assets.

- For ISS operations, a 72-hour advance screening is performed
- For Shuttle orbit operations, a 36-hour advance screening is performed
- If a vehicle is performing a maneuver during the screening period, OSA uses post-reboost trajectory data supplied by Mission Control Center-Houston (MCC-H) for screening

An automated process is used to detect any conjunctions within 10 x 40 x 40 km box (centered on the vehicle) using Special Perturbation (SP) processing

- Box dimensions are Radial x Downtrack x Crosstrack
- Any object found within this box has the tracking tasking level increased to improve (hopefully) its uncertainty in its current and predicted orbital trajectory
- OSA informs NASA if any object is found inside a 2 x 25 x 25 km box then creates and sends an Orbital Conjunction Message (OCM) to NASA which contains detailed information about the conjunction
- For Shuttle, the box size used for screening and reporting is altered for special operations (day of rendezvous, launch screening, etc.)

ISS Debris Avoidance Process

- **MCC-H trajectory specialists notify Flight Control Team and International Partners if a conjunction penetrates a $\pm 0.75 \times \pm 25 \times \pm 25$ km box**
 - Most conjunctions which are a real potential threat generally have radial miss distances less than 0.75 km. However, if an object with a greater radial miss is deemed a threat, then trajectory specialists will still alert the flight control team
- **MCC-H evaluates threat level to ISS and computes a probability of collision (PC) using the vector and covariance matrix information derived from JSpOC**
- **MCC-H assesses if planning for a debris avoidance maneuver is warranted and begins working maneuver options as needed, making a joint recommendation to their respective flight control teams.**
 - Future downrange constraints to the long-term trajectory are accounted for in maneuver planning

Maneuver thresholds are as follows (see Flight Rule B4-101):

- **$1E-05 \leq PC < 1E-04$ (Yellow Violation)**
 - A maneuver shall be performed ... unless the maneuver results in more than minimal impacts to operations or mission objectives. The requirement for the maneuver will be based on the magnitude and trends of the violation vs the impact of the maneuver.
- **$PC \geq 1E-04$ (Red Violation)**
 - A maneuver shall be performed ... unless the maneuver results in shuttle re-flight, vehicle hardware damage, additional EVA, or other significant operational impacts that increase the overall risk to the current or future crew or vehicle. The requirement for the maneuver will be based on the magnitude and trends of the violation vs the impact of the maneuver.

Shuttle Orbit Debris Avoidance Process

- **Shuttle trajectory specialists evaluate threat level to Shuttle and computes a probability of collision (PC) using MCC-H vector and covariance data for the Shuttle and JSpOC's vector and covariance data for the object.**
 - The PC method using Shuttle-derived covariance data has only been approved for propagations of 12 hours or less
 - For conjunctions greater than 12 hours into the future, a “box” method is used to determine the threat (see below)
- **Shuttle trajectory specialists send JSpOC predicted post-maneuver state vectors for screening against the rest of the catalog for a period of 36 (TBD) hours post-maneuver**
 - Shuttle should not be maneuvered into an greater threat
- **DAMs must be performed during crew wake periods since crew inputs are involved**
- **Maneuver thresholds are the same as ISS with additional wording for the case when a covariance does not exist (see Flight Rule A4-106):**
 - $1\text{E-}05 \leq \text{PC} < 1\text{E-}04$ (Yellow Violation)
 - If covariance data is unavailable, the yellow threshold will be based on a predicted miss distance between 1 km x 7 km x 7 km and 0.5 km x 4 km x 4 km
 - $\text{PC} \geq 1\text{E-}04$ (Red Violation)
 - If covariance data is unavailable, the red threshold will be based on a predicted miss distance less than 0.5 km x 4 km x 4 km

ISS Debris Avoidance Process - Cancellation

Once the Flight Control Team has committed to designing a debris avoidance maneuver (DAM) for the ISS, there are options which allow the team to cancel the DAM's execution.

In some instances, performing a DAM for an object which is no longer a threat may result in a trajectory that compromises upcoming trajectory goals. In this scenario, the flight control team may elect to cancel the DAM if the object no longer poses a threat to ISS.

ISS Debris Avoidance Maneuver (DAM) History

Date	Debris Object	Vehicle	Notes
06/13/99	1844 (SL-3 R/B)	FGB	Maneuver Execution FAILED. Two PC violations (1E-2 and 1E-3) early in event based on bad data
10/26/99	25422 (Pegasus R/B)	FGB	First successful ISS DAM and only DAM performed by FGB. Highest PC = 1E-03.
09/29/00	5143 (SL-3 R/B)	Progress 1P	Maneuver on Yellow threshold violation
02/10/01	87610 (Unknown Debris)	STS-98 (5A)	Shuttle Box method used
12/15/01	5730 (SL-8 R/B)	STS-108 (UF-1)	Shuttle PC method used
05/15/02	23279 (SL-8 R/B)	Progress 7P	PC = 1E-03 (red threshold violation)
05/30/03	25722 (MEGSAT)	Progress 10P	PC = 9E-04 (red threshold violation)
08/27/08	33246 (COSMOS 2421 Debris)	ATV-1	PC=2E-02 (red threshold violation) and largest PC calculated to date
03/22/09	26264 (CZ-4 Debris)	STS-119 (15A)	Red threshold violations on a multi-repeating conjunction. TCAs were during an EVA, so a Retrograde DAM was executed early by having orbiter hold attitude.
07/18/09	84180 (Unknown Debris)	STS-127 (2 JA)	TCA occurred 15 hours after STS-127 docking (during crew sleep). Due to the docking perturbations, a red threshold violation was computed and a reboost was performed by the Shuttle before the crew went to sleep.

722 Conjunction Notifications (through 12 July 2010)

10 Debris Avoidance Maneuvers Attempted

5 performed by ISS

1 attempted by ISS, but failed (ISS's first attempt)

4 performed by Shuttle during mated operations

Annual Maneuver Rate (theory suggests ~1.2 maneuvers/year)

~0.9 Maneuvers/year (including failed DAM)

~0.8 Maneuvers/year (not including failed DAM)

Recent Conjunction Items of Interest

August 27, 2008 (ISS Retrograde DAM): COSMOS 2421 debris (33246)

- Notable for: First ISS DAM attempted in 5 years, Retrograde DAM
- Complicating factors
 - Retrograde DAM – performing a posigrade DAM would violate Soyuz launch and landing constraints, as well as Shuttle rendezvous altitude constraints
 - DAM Clearing Assessment was very difficult due to multiple conjunctions in the vicinity if the DAM was performed
 - Eventually found a 1.0 m/s option that was technically clear with respect to Flight Rules (no post-burn conjunction within 48 hours of a maneuver)
 - The DAM option chosen with the best prospects still had one object that could be a potential problem 3 days into the future (Object 33048)
- COSMOS 2421 Debris, part 2 (Object 33048)
 - DAM was nominal for Object 33246 which resulted in a predicted conjunction with Object 33048 three days later
 - DAM planning to avoid Object 33048 began soon after the previous DAM executed
 - Ultimately, the PC dropped below the yellow threshold and cyclogram development was halted

Recent Conjunction Items of Interest

March 12, 2009 (Shelter in Soyuz): PAM-D debris (25090)

- Notable for: Late notification, crew placed in Soyuz
- Complicating factors
 - High eccentricity (>4200 km apogee makes many sensors useless)
 - High radial velocity (1 km/s made radial position unpredictable)
 - Extremely high drag (65 times ISS), makes object unpredictable
 - Low inclination (35 deg. eliminates most SSN sensors)
 - Small radar cross section (makes difficult to track)
 - Space weather prediction of geomagnetic spike did not occur as expected
 - Bottom Line - Only one sensor was able to track 25090 during conjunction
- Notification from JSpOC
 - TOPO notified at TCA-42 hours that 25090 would enter 2x25x25 km box
 - Usual screening horizon is 72 hours
 - At TCA-19 hours, prediction entered 0.75 x 25 x 25 km box
 - At this point, TOPO informed Russians and ISS Flight Control Team
 - ISS DAM template kick off process NLT TCA-28.5 hours

Recent Conjunction Items of Interest

March 23, 2009 (STS-119 Mated Operations): CZ-4 debris (26264)

- Notable for: Retrograde mated DAM during STS-119
 - MCC-H had been monitoring this repeating conjunction as a “no threat” item
 - Object had similar orbital period to the ISS/STS stack, so there were TCAs on multiple consecutive orbits
 - ISS/STS stack had a Loss of Attitude Control at ~TCA-48 hours, which pushed the radial miss distances much closer (within the 0.75 x 25 x 25 km box)
 - Probability of Collision calculations showed multiple red threshold violations
 - TCAs would occur during the next spacewalk
 - The posigrade delta-V needed to be safe would violate the rendezvous conditions necessary for the upcoming Soyuz – a small retrograde maneuver was planned
 - DAM was unique in that it was performed using the Shuttle to hold attitude control such that an overall retrograde trajectory perturbation was accomplished
- Due to the retrograde DAM, this object ultimately showed up as a repeating conjunction again in the week following STS-119 undocking.
 - No PC threshold violations occurred and no action was necessary

Recent Conjunction Items of Interest

April 9, 2009 (post-Soyuz undocking): Fengyun 1C debris (29822)

- Notable for: DAM planning initiated on account of post-Soyuz undocking trajectory
- Complicating factors:
 - Pre-undock trajectory indicated no DAM planning would be required
 - Soyuz undocking at TCA-30 hours moved ISS to <1 km from Fengyun at TCA (though larger radial miss)
 - Since collision probability requires ISS covariance, MCC-H had to wait for several USSTRATCOM tracks
 - Immediate GPS vector from ISS indicated a likely low- P_c , but TOPO currently has no verified covariance matrix available from ground filter
 - Russians stood by formal agreement after MCC-H request for extension
 - Much easier to ensure ISS tracking over a tracking site than small debris
 - Therefore, MCC-H gave GO for maneuver command build
 - Cancelled 4 hours later, as expected
- This object was relatively easy to track and predict

Recent Conjunction Items of Interest

May 16, 2010 (STS-132 Rendezvous): Unknown Debris (87761)

- Notable for: TCA occurred ~1 hour after docking
 - Docking perturbations would invalidate the Probability of Collision method
 - Not enough time post-docking to track the mated stack via C-Band to get an accurate prediction
 - Trajectory teams discussed the option of having ISS perform a stand-alone debris avoidance maneuver the evening prior to docking. However, this would require ISS to make a decision to perform a DAM without official PC
 - Trajectory teams discussed the possibility of having the Orbiter delay docking to ensure a good PC
 - Teams became comfortable with the perturbations from docking activities would not be large enough to statistically affect the overall risk